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ABSTRACT

The study identified dimensions of college mathematics experiences and analyzed their effects on choice of college major. Structural equation modeling was used to: (1) assess the role of five precollege variables on both the college mathematics experiences and changes of majors; (2) assess the role of the college mathematics experience on changes of majors; and (3) test the importance of four variables in identifying the "latent" construct, the college mathematics experience. Important interactions between students and their college mathematics experiences were found, and these interactions affected choice of majors and careers. The model explained 8% to 42% of the variance for dropout and change of major. Sixty-three percent of the students made some significant change in majors; 75% of these dropped out. In addition to mathematics grades, the mathematics frustration ratio is an important dimension. Expanded mathematics curricula provide legitimate opportunities for students with mathematical deficiencies to re-enter the scientific/technical talent pool. (MNS)

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Mathematics and College Students: The Dimensions and Effects of the College Mathematics Experience

by

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American society and its economic system are in the midst of a radical transition to a postindustrial era (Kahn, 1979). The pace has quickened, the rules are in a state of flux, and "change is the constant" (Cross, 1985, p. 8).

This transition, or "revolution," brings with it a rapid escalation in the demand for mathematically competent college graduates. As the National Science Board Commission on Precollege Education in Mathematics noted recently, technological literacy, communication, and higher problem-solving skills are the "basic capital of tomorrow's society" (National Science Board Commission on Precollege Education in Mathematics, 1982, p. v; see also Hurd, 1983). Further, as reliance on technology and higher problem solving increases, more and more fields need workers who have high levels of reasoning and mathematical competence. No longer is it only the scientists and engineers who need college-level mathematics, but professionals in business, the social sciences, allied health fields, and education as well.

Higher education has responded to these new demands by expanding the college mathematics curricula both horizontally and vertically. New courses have been added designed specifically for the mathematics competency requirements of fields such as the social sciences and business. In addition, the mathematics curricula on most campuses have been extended downward, thus affording students the possible option of recouping their high school mathematics deficiencies during college.

However, demand for mathematically-competent workers still outstrips supply. Many futurists and economic analysts (e.g., Kahn, 1979; Schultz, 1980) have expressed fear that these shortfalls in the mathematically competent labor supply will increase dramatically over the next 20 years,

threatening not only the economy and quality of life, but the national security as well.

All of this has created a critical need for educational researchers to identify problems in the mathematics progress of students at all levels. However, to date, research on students and mathematics has focused almost entirely on precollege mathematics and the lower mathematics achievement and participation rates of women and racial/ethnic minority students before they enter college. One of the most critical, and yet largely ignored, research areas is college mathematics and its impact on students in their progress toward scientific/technical, or math-based, careers.

Purpose of the Study

The purpose of this study was to evaluate the role college mathematics plays in students' changes from initial to final college majors. The study was built on the findings of research on precollege mathematics and students, extending the focus of attention to the college sphere. The study explored the dimensions of the college mathematics experience and the impact of this experience on changes from initial to final majors, particularly out of math-based majors.

To accomplish this, the study introduced and demonstrated a theoretical construct termed the "college mathematics experience." This theoretical, or "latent," construct was indexed by multiple indicators theorized in this study to measure the many aspects of a student's mathematics experience in college. In addition, the study assessed whether or not the expanded precalculus curriculum offers underprepared

students a legitimate second chance to recoup deficiencies and pursue math-based scientific/technical majors and, subsequently, careers.

Research and Developments in Mathematics and Choice of Majors

Mathematics and Choice of Majors

Researchers studying precollege mathematics and students have found that the generally lower high school mathematics participation and achievement of women and racial/ethnic minority students are the products of complex webs of cognitive, affective, behavioral, and background variables (Olstad, Juarez, Davenport, & Haury, 1981; Parsons et al., 1983). Such factors as sex-role stereotyping (Fox, 1976, 1981), causal attribution (Covington & Omelich, 1979), parents' education (Gemmill, Monteil, & Bustoz, 1982), and language (Cuevas, 1984) act to deter students from enrolling in elective high school mathematics courses. Further, research has shown that mathematics participation and achievement are related to high school students' career plans and intended college majors (Wise, 1978).

High school seniors' intended college majors have a relationship to final majors (Astin, 1982) and actual career after college (Wise, 1978). However, research on choice and change of major during college indicates that from 33% to 80% of students change majors during their college careers (Davis, 1965; Astin & Panos, 1969; Theophilides, Terenzini, & Lorang, 1984). Further, the direction of these changes has significant implications for the production of mathematically competent graduates. Changes in majors during college were found in these studies to be away

from math-based scientific/technical fields, particularly engineering, medicine, and the hard sciences.

Dimensions of the College Mathematics Experience

The horizontal and vertical expansion of curricula college mathematics provides a widened variety of possible paths students may use to navigate through required college mathematics and mathematics-preparatory courses. For example, a student may enroll in a "fast-track," one-semester college algebra course or the slower, two-semester equivalent. Failing to navigate the fast-track course, the student may either try again or switch to the slower track. Many students even retreat to a lower mathematics course and rebuild their competency to the required course level. In addition, a student may use withdrawal, switching, and retreating in combination in an even more complex attempt to navigate through mathematics requirements. Navigation, withdrawal, sequence, and subsequent frustration are all possible dimensions of a college student's college mathematics experience not fully reflected in grades or grade point averages.

Description of the Study

The study addressed the issues of identifying dimensions of the college mathematics experience and the effects of that mathematics experience on college major choice through both descriptive analysis and the development of structural-equation models. Central to this analysis was the concept of the college mathematics experience, how it is affected by high school mathematics exposure and achievement, and how the college

mathematics experience, in turn, affects students' progress in their college majors.

Precollege Variables

Precollege variables included in this study were gender, racial/ethnic minority group, high school mathematics cumulative grade point average, high school cumulative grade point average, mathematics exposure (Ethington & Wolfe, 1984), and American College Testing (ACT) mathematics score. High school transcripts provided information on the specific precollege mathematics courses taken, grades in all courses, and ACT mathematics score. All grade point averages were converted to a standardized 4.0 scale. High school mathematics exposure included algebra I, algebra II, geometry, trigonometry, calculus, and analysis.

The College Mathematics Experience

College mathematics experience was posited in this study to have multiple dimensions beyond those expressed by grades. Thus, the college mathematics experience was conceptualized as a latent, or unmeasurable, variable with multiple possible manifest, or observable and measurable, indicators: (1) college mathematics cumulative grade point average (CGPA) prior to final major choice, (2) college mathematics sequence--the levels of mathematics courses taken below the level required by the major, (3) navigation--a measure of the ease or difficulty with which a student completed mathematics courses, and (4) mathematics frustration ratio--a ratio of the credit hours of college mathematics courses in which a student received a low or failing grade ("D," "E," or "W") to the total mathematics credit hours attempted.

Shifts to Final Majors

Important also in the design of this study was the treatment of shifts to final college major. What was critical to the study of these changes in majors and their possible causes were not the many shifts from closely related majors in the same academic fields but the more dramatic shifts from majors requiring one level of mathematics to majors requiring either higher or lower levels of mathematics.

Major Classifications

Undergraduate majors were grouped for this study into seven classifications on the basis of the highest level of mathematics required for each major (see Table 1). Shift to final major was measured in terms of both the degree and direction of change from level of initial major to level of the final major. For example, a student who chose an initial major in engineering (a Level 8 major requiring calculus) and a final major in business (a Level 5 major requiring Mathematics for the Social, Management, and Life Sciences) experienced a negative shift in major downward three levels.

Structural-Equation Models

The general initial model tested for all discipline cluster groups is presented in Figure 1. Single-headed arrows represent hypothesized nonzero causal effects from one variable to the variable influenced. Causal effects are either direct or indirect through another variable. Double-headed arrows represent correlations between two variables, such as college mathematics experience and the non-mathematics experience.

Table 1

College Majors and Mathematics Requirements

Math-Level Group	Initial Groupings	% Students Initial Choice
Level 2 - no math requirement	English, foreign languages, social sciences, humanities, fine arts	17.4
Level 3 - Intermediate Algebra & Theory of Arithmetic	elementary/special education, nursing, communi-cations	9.7
Level 4 - College Algebra & Trigono-metry	psychology, premed	8.3
Level 5 - Mathematics for Social, Manage-ment & Life Sciences	management, finance, business admini-stration, wildlife biology	24.8
Level 6 - Mathematical Analysis	accounting, quan-titative analysis	9.8
Level 7 - Technical Calculus	technology	7.0
Level 8 - Calculus	engineering, computer science, physical science	23.0

The model has three temporal dimensions. The first is the precollege dimension. This includes five exogenous variables: (1) mathematics exposure, (b) high school mathematics cumulative CGPA, (3) high school CGPA, (4) gender, and (5) racial/ethnic minority status. Also included is one endogenous variable, ACT mathematics score.

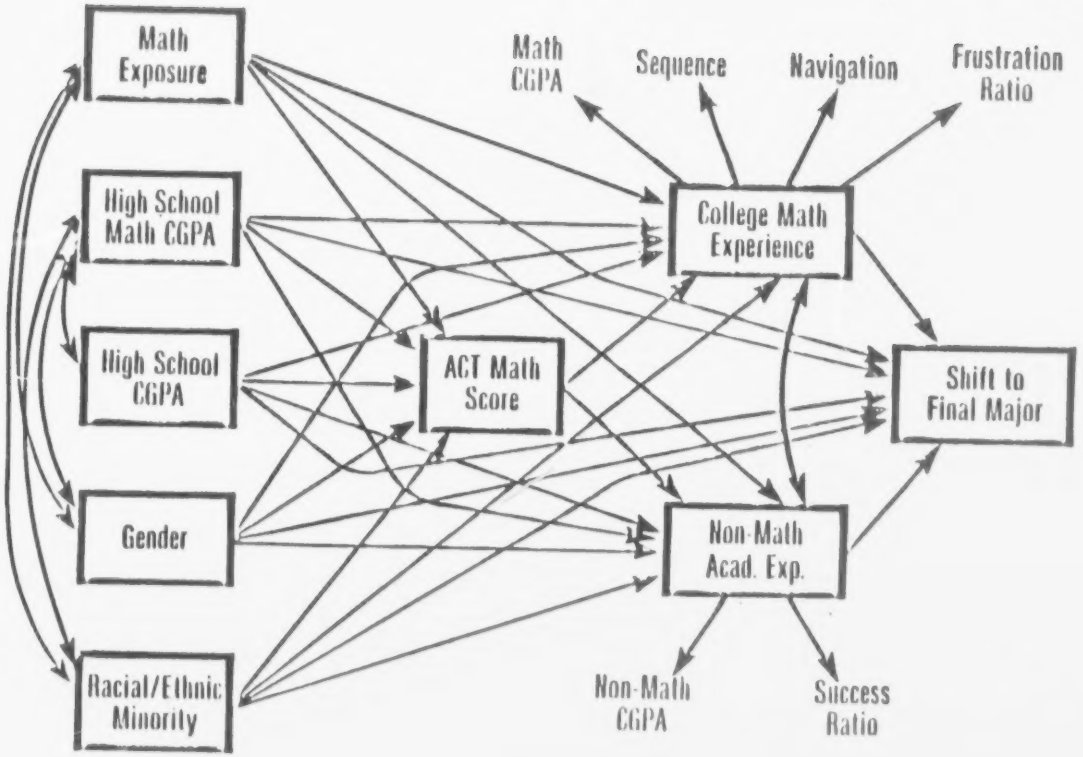

Figure 1. Initial Model

The second dimension, college experience, contains two endogenous theoretical variables I termed (1) college mathematics experience, and (2) non-mathematics academic experience. These were postulated to be predicted directly by each of the six precollege variables, and indirectly, through ACT math scores.

The third, or final outcome, dimension was shift to final major. In the initial model, shift to final major was considered to be the direct effect of each of the individual variables. In addition, the initial model considered shift to final major to be a function of a number of indirect effects.

Structural-equation models for each of the seven major clusters were constructed and tested depicting the relationship of students' precollege mathematics backgrounds, college mathematics and academic experiences, and progress in college majors. Further, the models were separately estimated for those students with 4th-year high school mathematics and those without 4th-year high school mathematics within each of the seven discipline areas.

Subjects

The study utilized data for 745 new freshmen enrolled at Arizona State University Fall Semester, 1981. Data were gathered from several record-keeping systems at Arizona State University.

It is important to note here two points about the curricula at Arizona State University. First, the university has no institution-wide mathematics requirement. All mathematics requirements are specific to the major. Second, in 1981, there were no mathematics placement tests.

Students enrolled in a particular level of mathematics on the basis of either advisement or their own perception of their mathematics abilities.

Failure and withdrawal rates in precalculus and calculus mathematics courses at Arizona State University were, and continue to be, high. Approximately 44% of students in mathematics courses in 1981 received grades of either "E" (failure) or "W" (withdrawal). Inclusion of withdrawals into consideration of progress is important because, for students enrolled in either a required course or a mathematics course prerequisite to a required course, withdrawal means a failure to successfully complete mathematics requirements and a possible setback or barrier to progress in their majors.

The study was longitudinal and tracked all mathematics course taking, grades, and changes in majors over a period of four years, Fall 1981 to Spring 1985.

Table 2 presents information on the demographic composition of the study group.

Precollege Backgrounds of Major Groups

High School Mathematics Background

Level 2 majors, such as English and fine arts, required no college mathematics competency. Not surprisingly, students in these majors entered college with less high school mathematics exposure, lower mathematics CGPA, and lower ACT mathematics scores than students in the math-based scientific/technical majors (see Table 3). Only 19% of the students in Level 2 majors had exposure to 4th-year high school mathematics, compared to an average of 32% for all students in the study.

Table 2

Demographics of Math-Level Initial Major Groups

Major Group	N	Percent Racial/Ethnic Minority	Gender	
			% Male	% Female
2	130	10.8%	36.2%	63.8%
3	72	4.2%	12.5%	87.5%
4	62	8.1%	40.3%	59.7%
5	185	4.3%	54.1%	45.9%
6	73	13.7%	54.8%	45.2%
7	52	5.8%	84.6%	15.4%
8	171	12.9%	81.3%	18.7%

Students in Level 3 initial majors, such as education and nursing, had the lowest high school mathematics CGPA and mathematics exposure rates of students in the study. In addition, the mean ACT mathematics score for this group (17.46) was substantially below that of students in all of the other initial major groups.

Level 4 majors, such as premed and psychology, required college algebra. Students in this group had the highest mean high school CGPA of all of the discipline cluster groups. However, the mathematics exposure rate and ACT mathematics scores of students in these majors were much lower than those of students in majors requiring higher levels of college mathematics. Only 27.4% had exposure to 4th-year high school math and only 77% had Algebra II, or third-year high school mathematics.

Table 3

High School Academic Background

Major Group	Mean High School CGPA (4.0 - 0.0)	Mean High School Math CGPA (4.0 - 0.0)	%ALGI	%ALGII	%GEOM	%TRIG	%ANALYSIS	%CALC	% With 4th Year Math*	ACT Math Score (Scale: 1-36) Mean	S.D.
2	3.11	2.61	94.6	66.9	88.5	15.4	5.4	4.6	18.5	19.62	6.42
3	3.10	2.53	94.4	65.3	87.5	12.5	8.3	0	16.7	17.46	5.93
4	3.26	2.83	93.5	77.4	87.1	21.0	8.1	4.8	27.4	20.19	6.48
5	3.12	2.69	91.4	67.0	88.1	17.3	7.6	4.3	23.8	20.38	6.28
6	3.09	2.68	84.9	72.6	94.5	21.9	13.7	12.3	37.0	20.89	6.05
7	3.08	2.59	100.0	80.8	96.2	36.5	5.8	1.9	38.5	23.52	5.63
8	3.24	3.05	96.5	88.3	91.8	32.7	18.7	22.2	55.0	24.67	5.98
ALL	3.15	2.75	93.6	74.1	90.1	22.1	10.3	8.7	31.9	21.20	6.54

* Note: % with 4th-year math is not the sum of % Trigonometry, % Analysis, and % Calculus. Percent with 4th-year math is computed on the basis of only one 4th-year math course per student and does not include double and triple 4th-year math course enrollment.

Level 5 majors, such as general business and management, required Mathematics for the Social, Management, and Life Sciences. Level 6 business majors in accounting and quantitative business analysis required a higher level course, Mathematical Analysis, including matrix algebra. While the mean high school CGPA and high school mathematics CGPA of both groups were similar, the two groups differed in high school mathematics exposure rates, particularly 4th-year mathematics. While only 23.8% of Level 5 students had 4th-year high school mathematics exposure, 37.0% of Level 6 students had 4th-year mathematics.

Levels 7 and 8 comprised the majors typically referred to as "scientific/technical." Level 7 students were all in technology majors requiring Technical Calculus. Level 8 majors, such as engineering, computer science, and the physical sciences, required the more theoretical college calculus. Level 8 and Level 7 students, respectively, had the highest mean ACT mathematics scores (23.52--Level 7; 24.7--Level 8) of all the disciplines. In addition, Level 8 students had the highest mean high school mathematics CGPA of all seven groups.

Gender Distribution of Initial Majors

The math-level discipline clusters demonstrated patterns of gender segregation among academic discipline fields similar to those reported in earlier literature on choice and change of majors (Davis, 1965; Astin & Panos, 1969) (see Table 4). Education and the social sciences were female dominated; engineering, computer science, the physical sciences, and technology were male dominated. However, the relatively low level of gender segregation of the study group in business fields is in striking contrast to earlier studies (Davis, 1965).

Table 4

Gender Distribution of Math-Level Initial Major Groups

Major Group	Gender	
	% Male	% Female
Level 2 - English foreign languages, social sciences, humanities, fine arts	36.2%	63.8%
Level 3 - elementary/ education, nursing, communications	12.5%	87.5%
Level 4 - psychology, premed	40.3%	59.7%
Level 5 - management, finance, business administration, wildlife, biology	54.1%	45.9%
Level 6 - accounting, quantitative analysis	54.8%	45.2%
Level 7 - technology	84.6%	15.4%
Level 8 - engineering, computer science, physical science	81.3%	18.7%

Results

Descriptive Data - The College Mathematics Experience

Table 5 provides data on the college mathematics experience variables for the seven initial major groups. One point brought out in Table 5 is the low college mathematics CPGAs of all groups. With only one exception (Level 6 accounting and quantitative business analysis majors), the mean

mathematics CGPA for each group was below the 2.00 students must receive in required mathematics courses to fulfill competency requirements of various majors. These low mathematics CGPAs were mirrored further in the high mathematics frustration ratios (40-50). In addition, Table 5 reveals a large range in percent of mathematics courses repeated (18%-78%) among the major groups.

Table 5

Mean Values of Manifest Variables Identifying the College Mathematics Experience

	College Mathematics Experience		
Major Group	Math GPA	Frustration Ratio	Percent Repeat
2	1.57	48.21	21
3	1.72	46.29	18
4	1.73	46.32	51
5	1.85	42.20	39
6	2.11	39.84	40
7	1.58	49.81	51
8	1.67	50.13	78

Note. "Frustration Ratio" is measured by the number of mathematics student credit hours in which the student received grades of "D," "E," or "W" to mathematics student credit hours attempted.

Level 2 majors. While Level 2 majors required no mathematics, Level 2 students included in this analysis voluntarily enrolled in at least one college mathematics course. Yet, their success rates were low. These students had the lowest mean college mathematics CGPA (1.57) of all

groups, coupled with a relatively high mathematics frustration ratio (48.21). However, perhaps because the mathematics courses were not required, students in Level 2 repeated a low 21% of their mathematics courses.

Level 3 majors. Level 3 majors required the lowest level of college mathematics. Level 3 students had a mid-range mathematics frustration ratio of 46.29; however, they repeated a low 18% of their mathematics courses. While failing students in some Level 3 majors had the option of enrolling in other mathematics courses to fulfill their mathematics requirement, students in majors with specific mathematics course requirements (such as nursing and elementary education) had only the options of either repeating the course, changing majors to Level 2, or dropping out of school.

Level 4 majors. Level 4 majors required college algebra. Values for Level 4 students for college mathematics experience were mid-range among the seven initial major groups. However, Level 4 students repeated a fairly high 51% of their mathematics courses.

Level 5 and Level 6 majors. Level 5 majors had a mean college mathematics CGPA of 1.85 and a mean mathematics frustration ratio of 42.20. Level 6 majors in accounting and quantitative business analysis had the highest mean college mathematics CGPA (2.11) and lowest mathematics frustration ratio (39.84) of all groups. Students in both groups repeated mathematics courses at about the same rate, above that of Levels 2 and 3, and below Levels 4, 7, and 8.

Level 7 and Level 8 majors. Students majoring in Levels 7 and 8 scientific/technical fields experienced the highest mathematics

frustration ratios (Level 7--49.81; Level 8--50.13) of students in all seven major groupings. In addition, they repeated the highest percentage (Level 7--51%; Level 8--78%) of mathematics courses of students in the seven initial major groups.

Descriptive Data - Mathematics Sequence and Within-Group Differences

Table 6 displays the within-group differences in mathematics sequence for Levels 4 through 8, those level groupings with lower-level mathematics sequence options. Exposure to 4th-year high school mathematics (trigonometry, analysis, and/or calculus) was a significant factor differentiating the college mathematics course sequence of students in each math-level initial major grouping.

The differences in course sequence between students with and those without 4th-year high school mathematics are particularly striking for Levels 4 and 5. Over 60% of Level 4 students without 4th-year mathematics took MAT 106, Intermediate Algebra, compared to only 6.2% of those students with 4th-year mathematics. Students in Level 5 majors had more options, including MAT 115 or 117 and 118 college algebra sequences. Yet, over 70% of Level 5 students without 4th-year high school mathematics and 23.37% of those with 4th-year high school mathematics enrolled in MAT 106.

Fourth-year high school mathematics also made a difference in the mathematics course sequence of Level 6 students. While 77.8% of those with 4th-year high school mathematics did take lower level college mathematics, 55.6% enrolled at only one level below the MAT 210, Mathematical Analysis, required. On the other hand, 62.2% of those without 4th-year high school mathematics enrolled three levels below, in MAT 106.

Table 6

Percentage Taking Lower-Level Mathematics Sequence

Major Group	Students With 4th-Year High School Math		Students Without 4th-Year High School Math	
	N	%	N	%
4	17	6.2	45	60.5
5	44	37.2	141	74.3
6	27	77.8	46	93.3
7	20	75.0	32	87.1
8	94	71.3	77	85.5

Note. Math sequence is not applicable to Level 2 with no mathematics requirement and Level 3 with no lower-level mathematics options.

What are important also are the high percentages of scientific/technical students in Levels 7 and 8 who entered college with the requisite 4th-year high school mathematics yet took college mathematics below the entering level calculus required by their majors. Over 71% of the students in Level 8 majors who entered college with 4th-year high school mathematics took lower level college mathematics.

Descriptive Data - Changes in Majors

The most dramatic change of major was dropout; 47.9% of the study group dropped out before graduating and were not reenrolled before or during the Spring Semester, 1985. The great majority (70.2%) of the remaining persisting students made no change from their major clusters.

Not surprisingly, the most stable majors were those requiring no mathematics. However, the second most stable were the engineering, computer science, and physical science majors requiring the highest level of mathematics (see Table 7).

Table 7

Dropout and Stability Rates by Math-Level Major Groups

Major Group	% Dropout	% Stability
2	43.1	40.0
3	47.2	37.5
4	51.6	37.1
5	50.8	33.5
6	37.0	32.9
7	61.5	23.1
8	48.0	39.8
All	47.9	36.0

Final Models

In the process of refinement of the models, each model was modified systematically with the overall objective of improving the fit while eliminating direct paths from precollege background variables to the final outcome, shift to final major. The modification process improved each of the models, with one exception: the direct path between gender and shift

to final major for Level 5 business majors was found to contribute to the fit of the model and thus was retained.

Results demonstrated that there are great differences in the factors and their interrelationship affecting the college academic experiences and changes of majors of students in different major clusters. Final models varied both among the seven math-level discipline clusters and between each mathematics exposure subgroup within each cluster. (See Appendix A-1 to A-7 for path coefficient values and significance.)

College mathematics experience had a significant effect on shift to final majors in five of the twelve models. Further, the relative importance of three of the four manifest variables (college mathematics grade point average, sequence, and navigation) used to identify the college mathematics experience differed among the seven initial major groups. (See Appendix B for path coefficient values and significance.) Sequence was a significant factor in the college mathematics experience only for Level 5 business majors. Navigation was important for Level 6 accounting and quantitative business analysis, Level 5 business, and all Level 4 majors. Math CGPA was significant in identifying the college mathematics experience of all except Level 7 technology majors. However, mathematics frustration ratio was a significant factor in the college experiences of all students in this study.

Conclusions

This study and its results indicate that there are important interactions between students and their college mathematics experiences, and these interactions impact choice of majors and careers, as well as

dropout. The model developed in this study was successful in explaining anywhere from 8% to 42% of the variance in dropout and changes of majors for students in different major cluster groups. (Table 8 provides a summary of the final model statistics for each of the seven major groups.) Further, the study demonstrated that there are great differences in the factors and their inter-relationships affecting the mathematics experiences of students in different academic fields. The model provides an initial base through which researchers can further explore the interaction between students and their college mathematics experiences.

Second, the study confirmed earlier findings by other researchers (Davis, 1965; Astin & Panos, 1969; Theophilides, Terenzini, & Lorang, 1984) that the majority of college students make some significant change from initial to final majors during their college careers. Sixty-three percent of the students in this study changed major clusters. However, 75% of this movement was dropout.

Further, the study demonstrated that other factors in addition to mathematics grades (CGPA) are important in the mathematics experiences of students in majors requiring different levels of mathematics competency. In particular, the mathematics frustration ratio, including all unproductive attempts at mathematics courses, is an important additional dimension in the mathematics experiences of students in all areas.

Finally, results of this study indicate that the expanded mathematics curricula provide students entering college with mathematics deficiencies legitimate opportunities to recoup their losses and re-enter the scientific/technical talent pool. For example, in the major grouping that

Table 8

Summary

Major Group	Final X^2	Final df	Ratio X^2:df	R^2 with/without
2	83.25	59	1.41	.224/.166
3	44.85	36	1.25	.221[a]
4	91.47	36	2.54	.084[a]
5	149.55	80	1.87	.094/.287
6	117.34	94	1.25	.404/.416
7	139.64	98	1.42	.191/.313
8	190.42	96	1.98	.317/.285

[a]Levels 3 and 4 had no separate mathematics exposure subgroup estimations.

included engineers and the physical sciences, over one third of the students who persisted in these majors over four years were students who had entered college without 4th-year high school mathematics and enrolled in lower-level mathematics before calculus in college.

What these findings say is that while precollege mathematics preparation is important in the process of producing mathematically competent college graduates, it is not the whole story. College mathematics experience is a critical factor, with multiple dimensions, that must be explored more fully if we are to understand and, hopefully, improve the production of this vital labor force.

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Table A-1

Standardized Path Coefficients in Final Models for Level 2 Initial Majors

Independent Variable	DEPENDENT VARIABLE: ACT Math Score With Subgroup	ACT Math Score Without Subgroup	College Mathematics Experience With Subgroup	College Mathematics Experience Without Subgroup	Non-Mathematics Academic Experience With Subgroup	Non-Mathematics Academic Experience Without Subgroup	Shift to Final Major With Subgroup	Shift to Final Major Without Subgroup
Math Exposure	-.147	.229**	.195	.138	.095	.196*	0	0
High School Math CGPA	.661*	.279**	.311	.212*	.001	.207*	0	0
High School CGPA	-.184	-.032	.297	.051	.509*	.208*	0	0
Gender	-.434*	-.379**	-.299	.075	-.009	.015	0	0
Racial/Ethnic Minority Status	No Racial/Ethnic Minority Status Variable Level 2							
ACT Math Score	0	0	.143	.022	.347	.010	0	0
College Math Experience	0	0	0	0	0	0	.240	.110
Non-Math Academic Experience	0	0	0	0	0	0	.261	.339**
Shift to Final Major	0	0	0	0	0	0	0	0

* $p < .05$ ** $p < .01$

Table A-2

Standardized Path Coefficients in Final Model for Level 3 Initial Majors

Independent Variable	DEPENDENT VARIABLE			
	ACT Math Score	College Mathematics Experience	Non-Mathematics Academic Experience	Shift to Final Major
Math Exposure	.234*	-.059	-.043	0
High School Math CGPA	.238*	-.008	-.012	0
High School CGPA	.183	.074	.125	0
Gender	-.093	.200*	.190*	0
Racial/Ethnic Minority Status	-.219*	-.088	-.020	0
ACT Math Score	0	.255*	.108	0
College Math Experience	0	0	0	.187
Non-Math Academic Experience	0	0	0	.338**
Shift to Final Major	0	0	0	0

* $p < .05$ ** $p < .01$

Table A-3

Standardized Path Coefficients in Final Model for Level 4 Initial Majors

Independent Variable	DEPENDENT VARIABLE: ACT Math Score	College Mathematics Experience	Non-Mathematics Academic Experience	Shift to Final Major
Math Exposure	.476**	.078	.021	0
High School Math CGPA	.476**	.227	.121	0
High School CGPA	-.060	.383**	.513**	0
Gender	.046	.046	.051	0
Racial/Ethnic Minority Status	-.205*	-.272**	-.136	0
ACT Math Score	0	.067	-.127	.230
College Math Experience	0	0	0	-.160
Non-Math Academic Experience	0	0	0	.284
Shift to Final Major	0	0	0	0

* $p < .05$ ** $p < .01$

Table A-4

Standardized Path Coefficients in Final Models for Level 5 Initial Majors

Independent Variable	DEPENDENT VARIABLE: ACT Math Score With Subgroup	ACT Math Score Without Subgroup	College Mathematics Experience With Subgroup	College Mathematics Experience Without Subgroup	Non-Mathematics Academic Experience With Subgroup	Non-Mathematics Academic Experience Without Subgroup	Shift to Final Major With Subgroup	Shift to Final Major Without Subgroup
Math Exposure	.076	.368**	-.217	.271**	.120	.102	0	0
High School Math CGPA	.145	.055	.331	.090	.130	.148*	0	0
High School CGPA	.276	.151	-.198	.288*	.292	.301*	0	0
Gender	-.319*	-.291**	.133	.130	-.089	.169*	-.299	-.225**
Racial/Ethnic Minority Status	No Racial/Ethnic Minority Status Variable Level 5							
ACT Math Score	0	0	.011	.103	-.399**	.091	0	0
College Math Experience	0	0	0	0	0	0	.251	.284**
Non-Math Academic Experience	0	0	0	0	0	0	-.021	.313*
Shift to Final Major	0	0	0	0	0	0	0	0

* $p < .05$ ** $p < .01$

Table A-5

Standardized Path Coefficients in Final Models for Level 6 Initial Majors

Independent Variable	DEPENDENT VARIABLE: ACT Math Score With Subgroup	ACT Math Score Without Subgroup	College Mathematics Experience With Subgroup	College Mathematics Experience Without Subgroup	Non-Mathematics Academic Experience With Subgroup	Non-Mathematics Academic Experience Without Subgroup	Shift to Final Major With Subgroup	Shift to Final Major Without Subgroup
Math Exposure	-.497**	.254*	-.013	.185	.036	-.080	0	0
High School Math CGPA	.771**	.218	-.289	.171	.075	-.353	0	0
High School CGPA	-.309	.191	.737**	.176	.281*	1.000**	0	0
Gender	.072	.106	-.382	.112	-.019	-.453**	0	0
Racial/Ethnic Minority Status	-.030	-.243*	-.130	-.026	-.261*	-.476*	0	0
ACT Math Score	0	0	.536**	.259*	.199	.268*	0	0
College Math Experience	0	0	0	0	0	0	.322*	.348*
Non-Math Academic Experience	0	0	0	0	0	0	.325*	.378*
Shift to Final Major	0	0	0	0	0	0	0	0

* $p < .05$ ** $p < .01$

Table A-6

Standardized Path Coefficients in Final Models for Level 7 Initial Majors

Independent Variable	DEPENDENT VARIABLE: ACT Math Score With Subgroup	ACT Math Score Without Subgroup	College Mathematics Experience With Subgroup	College Mathematics Experience Without Subgroup	Non-Mathematics Academic Experience With Subgroup	Non-Mathematics Academic Experience Without Subgroup	Shift to Final Major With Subgroup	Shift to Final Major Without Subgroup
Math Exposure	-.142	.485**	.038	-.185	-.225*	-.024	0	0
High School Math CGPA	.409	.209	.352	.055	-.002	-.390*	0	0
High School CGPA	.218	.239	.039	.177	.620*	.610**	0	0
Gender	.057	.099	-.177	.313*	.027	.179	0	0
Racial/Ethnic Minority Status	-.158	-.257*	-.380*	-.003	-.413**	.134	0	0
ACT Math Score	0	0	.158	.375*	.009	.401*	0	0
College Math Experience	0	0	0	0	0	0	.542*	-.290
Non-Math Academic Experience	0	0	0	0	0	0	-.396	.634*
Shift to Final Major	0	0	0	0	0	0	0	0

* $p < .05$ ** $p < .01$

Table A-7

Standardized Path Coefficients in Final Models for Level 8 Initial Majors

Independent Variable	DEPENDENT VARIABLE: ACT Math Score With Subgroup	ACT Math Score Without Subgroup	College Mathematics Experience With Subgroup	College Mathematics Experience Without Subgroup	Non-Mathematics Academic Experience With Subgroup	Non-Mathematics Academic Experience Without Subgroup	Shift to Final Major With Subgroup	Shift to Final Major Without Subgroup
Math Exposure	-.030	.310**	.075	.170	-.095	.035	0	0
High School Math CGPA	.393**	-.112	.246*	.333*	.130	.018	0	0
High School CGPA	.032	.415*	.300*	-.045	.400*	.318*	0	0
Gender	.027	.190	-.111	-.019	-.097	-.028	0	0
Racial/Ethnic Minority Status	-.244**	-.379*	-.291**	-.194	-.019	-.150	0	0
ACT Math Score	0	0	-.070	.087	-.043	.129	0	0
College Math Experience	0	0	0	0	0	0	.474*	.236
Non-Math Academic Experience	0	0	0	0	0	0	.106	.423*
Shift to Final Major	0	0	0	0	0	0	0	0

* $p < .05$ ** $p < .01$

Table 8

Standardized Path Coefficients for the Manifest Variables in Each Initial Major Level

Level	Independent Variable	DEPENDENT VARIABLE					
		Math CGPA	Sequence	Navigation	Frustration Ratio	Non-Math CGPA	Success Ratio
2	College Math Exp.	1.003**	NA	-.112	-.831**	--	--
	Non-Math Academic Exp.	--	--	--	--	.966**	.766**
3	College Math Exp.	1.031**	NA	-.144	-.819**	--	--
	Non-Math Academic Exp.	--	--	--	--	1.127**	.707**
4	College Math Exp.	1.005**	NA	-.353**	-.834**	--	--
	Non-Math Academic Exp.	--	--	--	--	1.014**	.869**
5	College Math Exp.	.945**	-.254**	-.240**	-.856**	--	--
	Non-Math Academic Exp.	--	--	--	--	1.004**	.729**
6	College Math Exp.	-1.072**	.151	.204*	.904**	--	--
	Non-Math Academic Exp.	--	--	--	--	1.080**	.834**
7	College Math Exp.	.941**	-.016	-.153	-.917**	--	--
	Non-Math Academic Exp.	--	--	--	--	.931**	.843**
8	College Math Exp.	.918**	-.108	-.093	-.914**	--	--
	Non-Math Academic Exp.	--	--	--	--	.968**	.817**

* $p < .05$ ** $p < .01$